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LEVEL

NARROW AND BROAD REGION DISPERSION OF LONG-PERIOD SURFACE WAVES

TECHNICAL REPORT NO. 16

VELA NETWORK EVALUATION AND AUTOMATIC PROCESSING RESEARCH

Prepared by
Rudolf Unger

TEXAS INSTRUMENTS INCORPORATED
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Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER
Alexandria, Virginia 22314

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Monitoring Research Office
ARPA Program Code No. 7F10
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11 October 1978

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Examples of both narrow and broad region dispersion analysis for long-period surface waves are presented. Narrow region dispersion analysis of Kuriles/Kamchatka earthquake signals recorded at Guam, by means of moving-window maximum entropy spectral analysis, indicates strong multipathing in the 3.0 to 4.5 km/sec group velocity range, causing poor polarization filter performance. In contrast, between 2.0 and 3.0 km/sec

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Broad region dispersion models for the North American and Asian continents were generated using previously reported group velocity data for Nevada Test Site and Eastern Kazakh presumed nuclear explosion signals recorded at world-wide stations. These models facilitate frequency-dependent surface wave magnitude measurement.

ABSTRACT

Examples of both narrow and broad region dispersion analysis for long-period surface waves are presented. Narrow region dispersion analysis of Kuriles/Kamchatka earthquake signals recorded at Guam, by means of moving-window maximum entropy spectral analysis, indicates strong multipathing in the 3.0 to 4.5 km/sec group velocity range, causing poor polarization filter performance. In contrast, between 2.0 and 3.0 km/sec the signals are well defined, resulting in a good polarization filter response. The dispersion for this region seems quite diverse.

Broad region dispersion models for the North American and Asian continents were generated using previously reported group velocity data for Nevada Test Site and Eastern Kazakh presumed nuclear explosion signals recorded at world-wide stations. These models facilitate frequency-dependent surface wave magnitude measurement.

ACKNOWLEDGMENTS

The broad-region dispersion model and the method for frequency-dependent surface wave magnitude measurement were suggested by Dr. R. L. Sax. The text and figures were prepared for printing by Mrs. C. B. Saunders and Ms. B. Olson.

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SECTION I
INTRODUCTION

A high-resolution dispersion analysis algorithm was developed during a study on the feasibility of time-variant, dispersion-related filtering (DRF) of long-period (LP) surface waves (Unger, 1976). In preparation of an attempt to evaluate this DRF on a large, regional data base, the dispersion analysis algorithm was applied to the waveforms of five strong events in the Kuriles-Kamchatka region. These five events were recorded at the Seismic Research Observatories (SRO) station GUMO at Guam ($\Delta \sim 30^{o}$).

The dispersion analysis for this region-station combination bears directly on the LP surface wave polarization results obtained for the same data base (Strauss, 1978). The quality of the latter results, i.e., improvements over bandpass filtering of approximately 0.5 M_s in both detection and M_s measurement capability, equals or exceeds those projected for a LP phase detector (Unger, 1978) and for the DRF (Unger, 1976). Moreover, the DRF can only be applied to regional data, since it operates with regional dispersion curves. In contrast, the polarization filter can be applied universally, and its operation can possibly be automated with relatively little effort. Further evaluation of the DRF in its present form, therefore, was halted. Instead, broad dispersion models were composed for the Asian and North American continents from data reported by Sun (1977). Based on these models, R. L. Sax conceived a different form of DRF for the special purpose of measuring frequency-dependent surface wave magnitudes in corresponding group velocity windows. This algorithm is being applied in the evaluation of a multivariate discrimination package (Sax et al., 1978).

In Section II of this report, we discuss the Kuriles-Kamchatka-to-Guam dispersion data, and their effect on LP surface wave polarization filtering. Section III describes the composition of the broad-region dispersion models, and the ensuing special purpose DRF algorithm. The report is summarized in Section IV and related material is listed in Section V.

SECTION II

KURILES/KAMCHATKA-GUAM DISPERSION

The moving-window maximum entropy spectral analysis program (Unger, 1976) was applied to the vertical Rayleigh waves of five strong events in the Kuriles-Kamchatka region, recorded at GUMO. The path is purely oceanic. The waveforms were low-pass filtered with a fourth-order Butterworth filter with a cut-off frequency of 0.06 Hz. The sample interval is 8 seconds. The length of the moving window is 20 samples (160 sec), and the number of correlation lags used in the maximum entropy spectrum generation is 6 samples (48 sec). These parameters were found to give the most plausible results in the DRF feasibility study (Unger, 1976).

The results are presented in Figure II-1 which shows the 8 second sampled waveform, the time-variant spectra, and the group velocity curves, respectively. The solid curves represent the relative spectral power of waveform windows centered 80 seconds apart. The spectral power is in the direction of the time axis. The origin level of each spectrum is at the indicated travel time. The bar above the spectra is the spectral power dB scale relative to the spectral power origin level annotated below each figure.

Figure II-2 is a composite of the five group velocity curves of Figure II-1, for velocities between 2.0 and 5.0 km/sec.

The fragmented character of the dispersion curves, in particular in the 3.0 to 4.5 km/sec range, suggests a strong multipathing effect at the lower frequencies (0.02 to 0.04 Hz). There is some consistency in the dispersion branches between 2.0 and 3.0 km/sec, where the waveforms fluctuate in frequency only between 0.045 and 0.055 Hz.

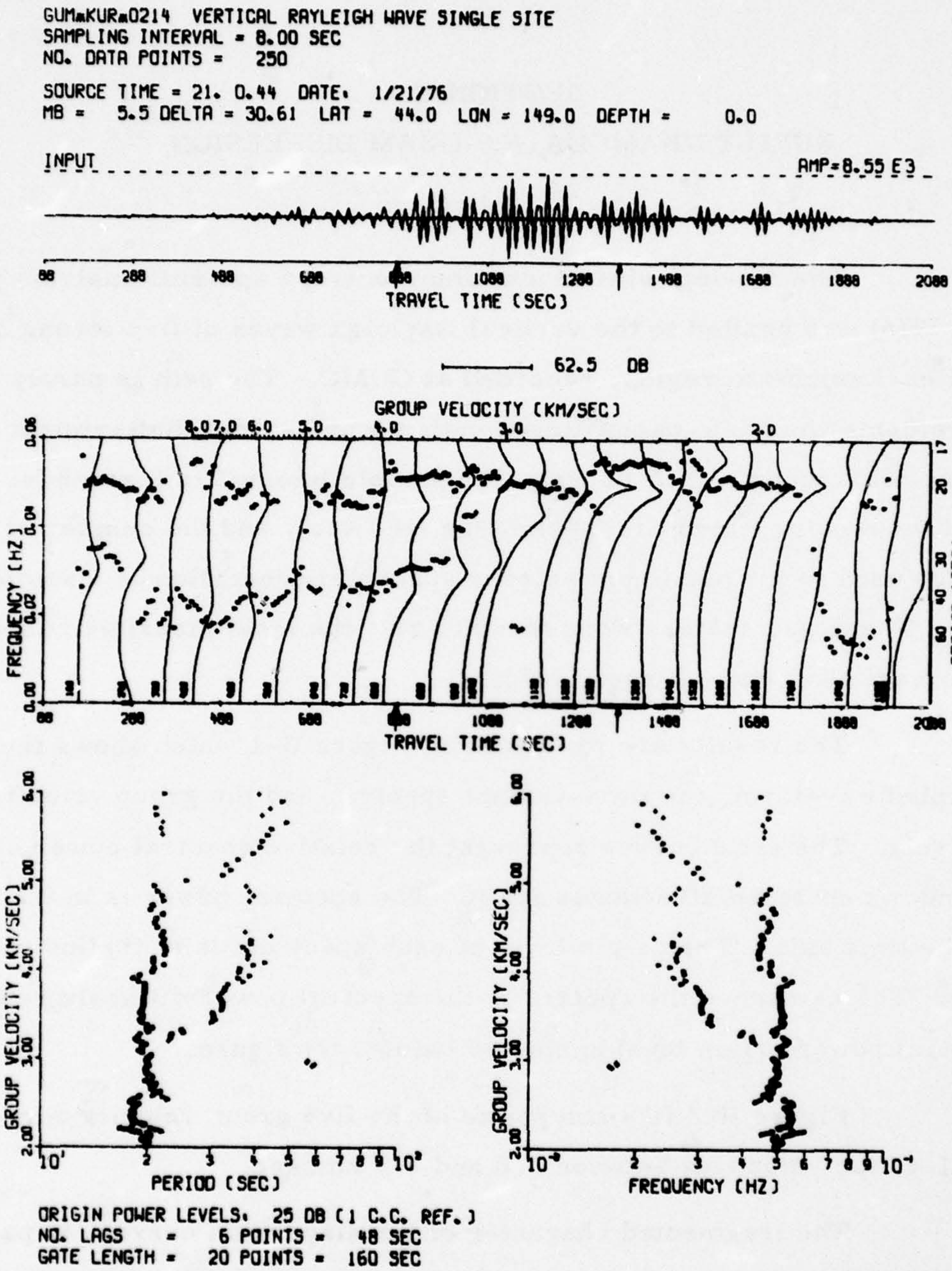


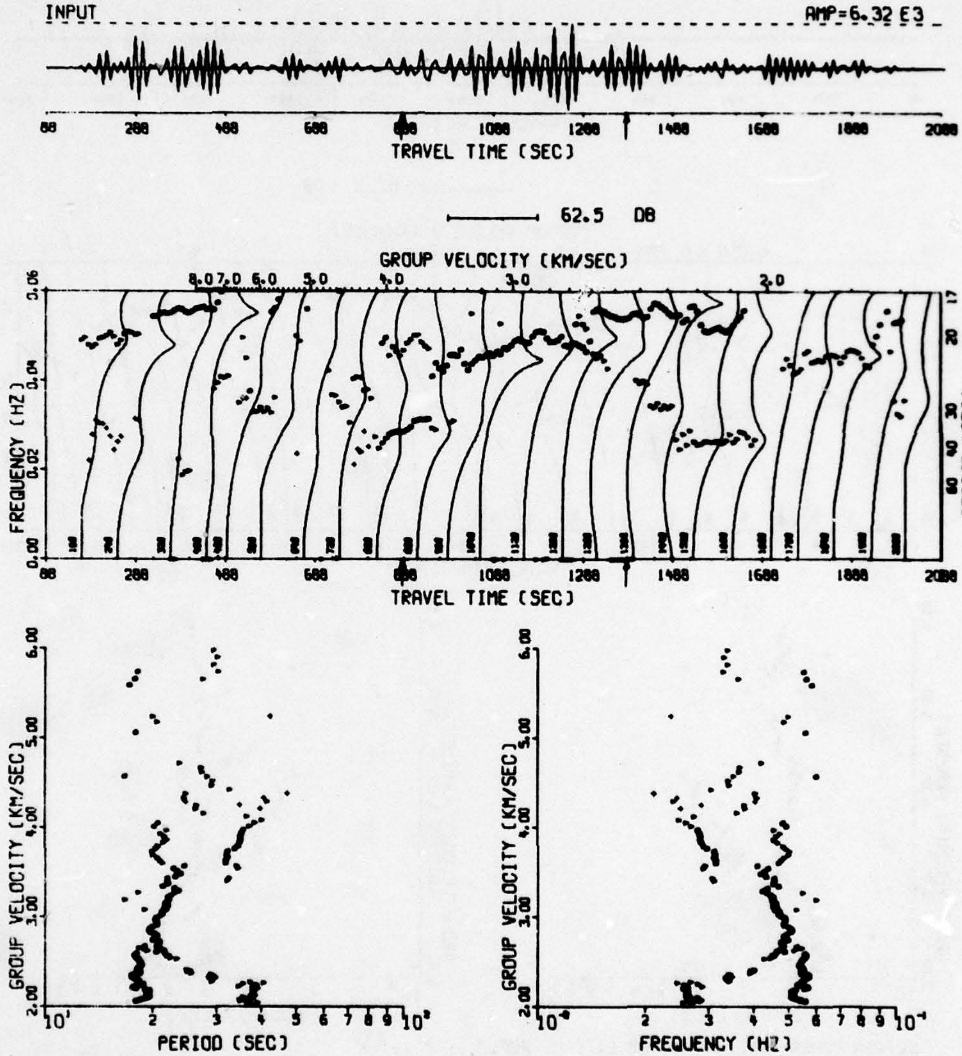
FIGURE II-1

KURILES/KAMCHATKA-GUAM DISPERSION

(PAGE 1 OF 5)

GUM*KUR*0247 VERTICAL RAYLEIGH WAVE SINGLE SITE
SAMPLING INTERVAL = 8.00 SEC
NO. DATA POINTS = 250

SOURCE TIME = 17.49. 3 DATE: 1/22/76
MB = 5.7 DELTA = 30.61 LAT = 44.0 LON = 149.0 DEPTH = 0.0



ORIGIN POWER LEVELS: 35 DB (1 C.C. REF.)
NO. LAGS = 6 POINTS = 48 SEC
GATE LENGTH = 20 POINTS = 160 SEC

FIGURE II-1

KURILES/KAMCHATKA-GUAM DISPERSION
(PAGE 2 OF 5)

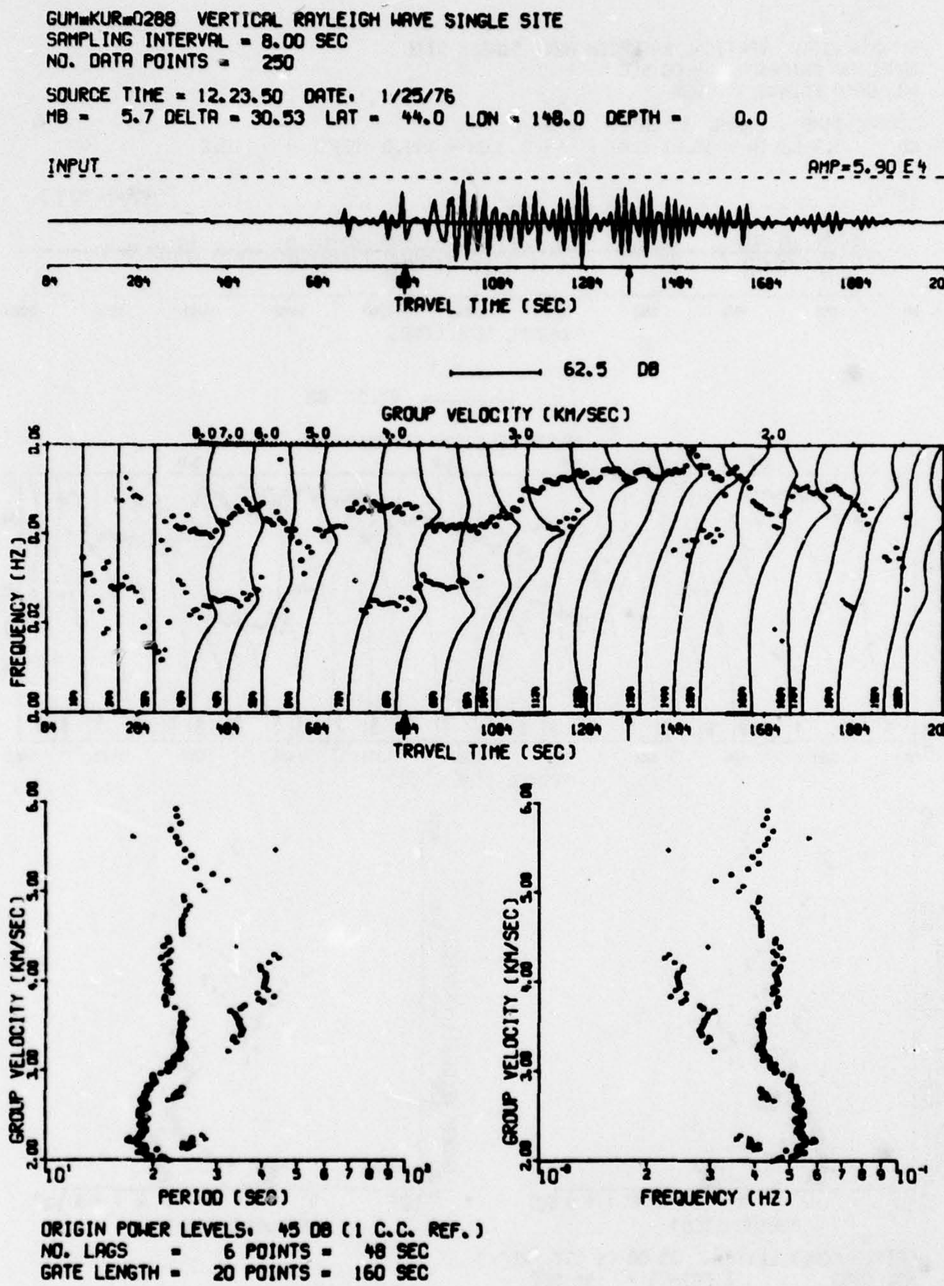


FIGURE II-1

KURILES/KAMCHATKA-GUAM DISPERSION
(PAGE 3 OF 5)

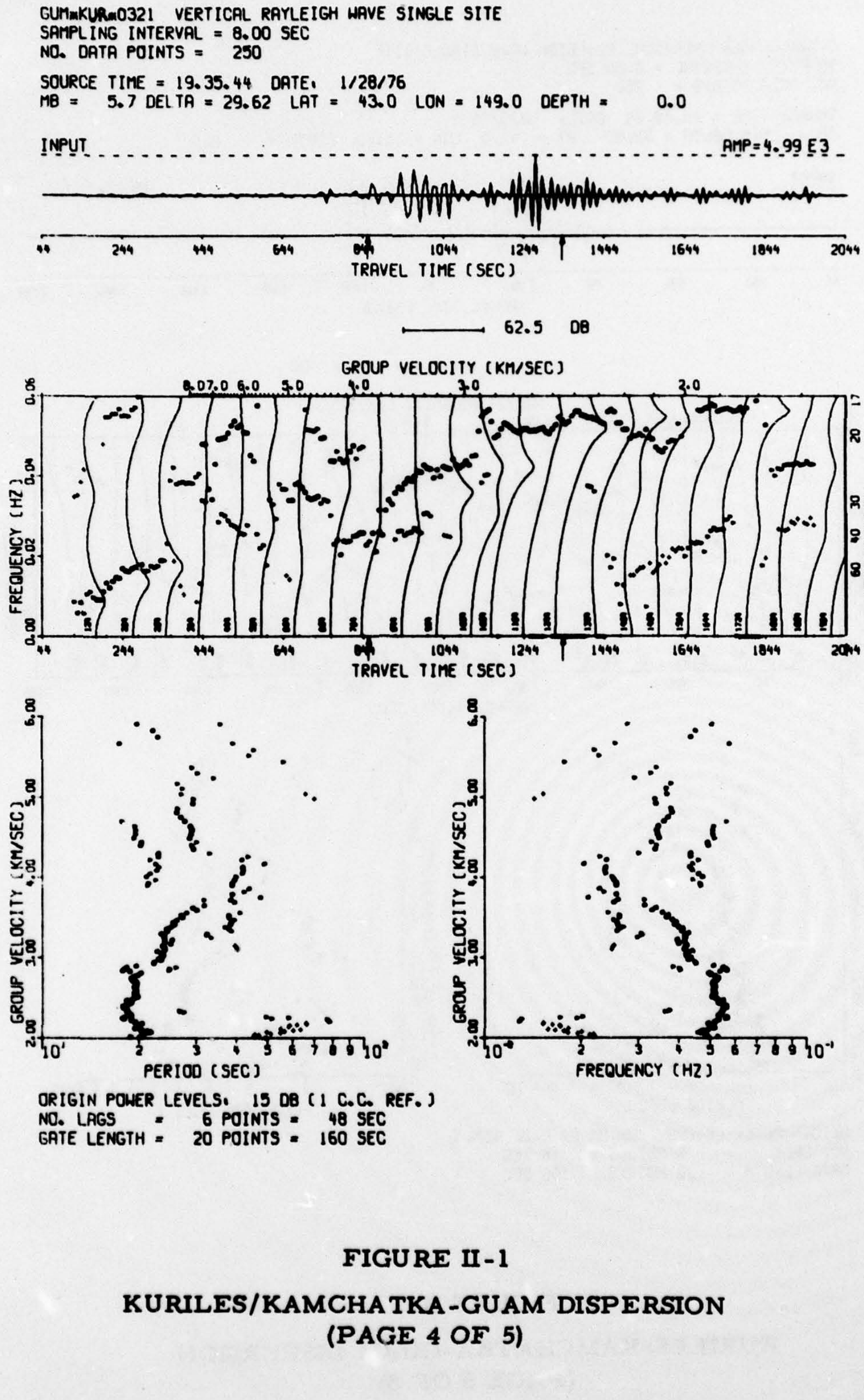


FIGURE II-1

KURILES/KAMCHATKA-GUAM DISPERSION
(PAGE 4 OF 5)

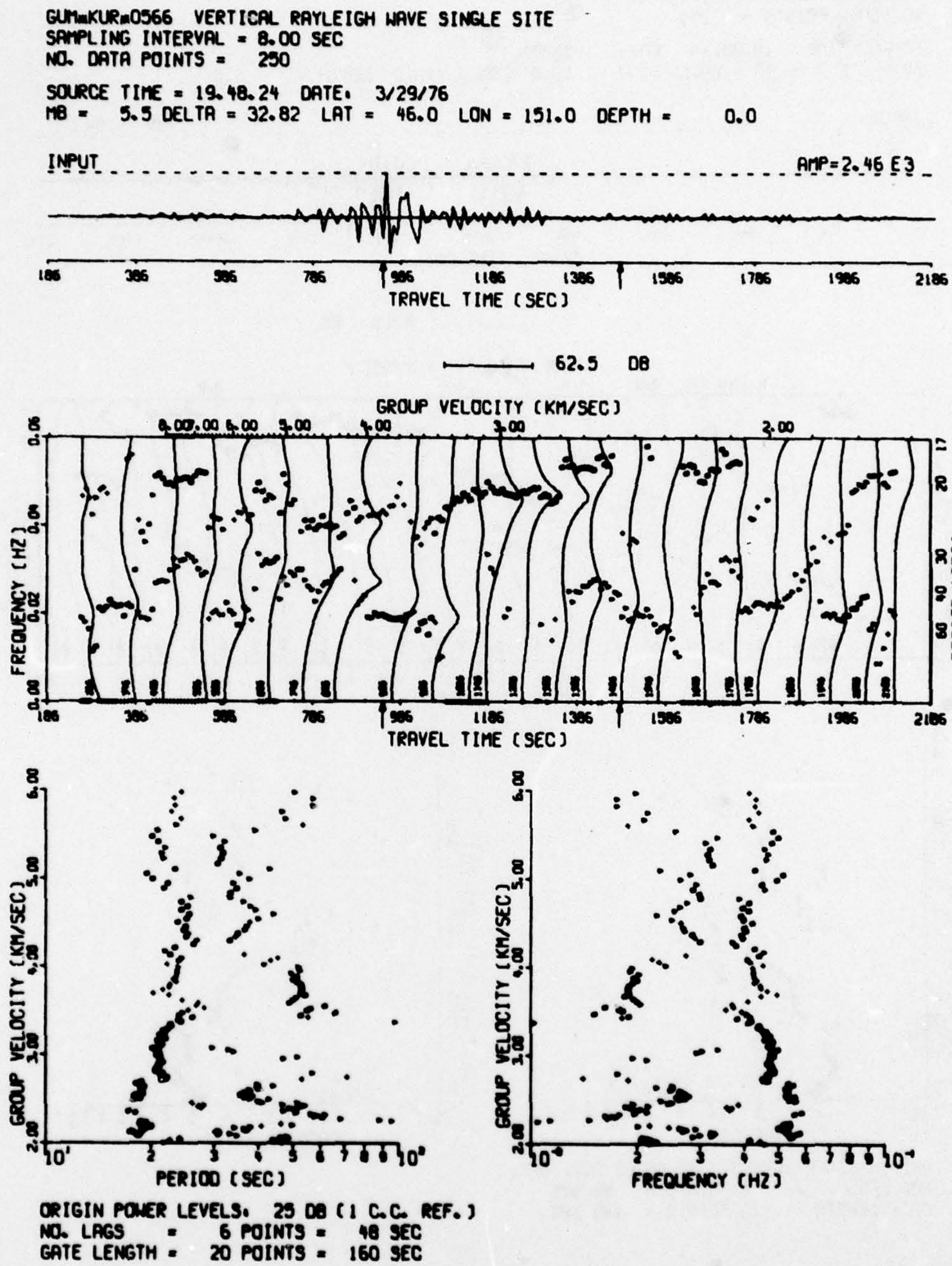


FIGURE II-1

KURILES/KAMCHATKA-GUAM DISPERSION
(PAGE 5 OF 5)

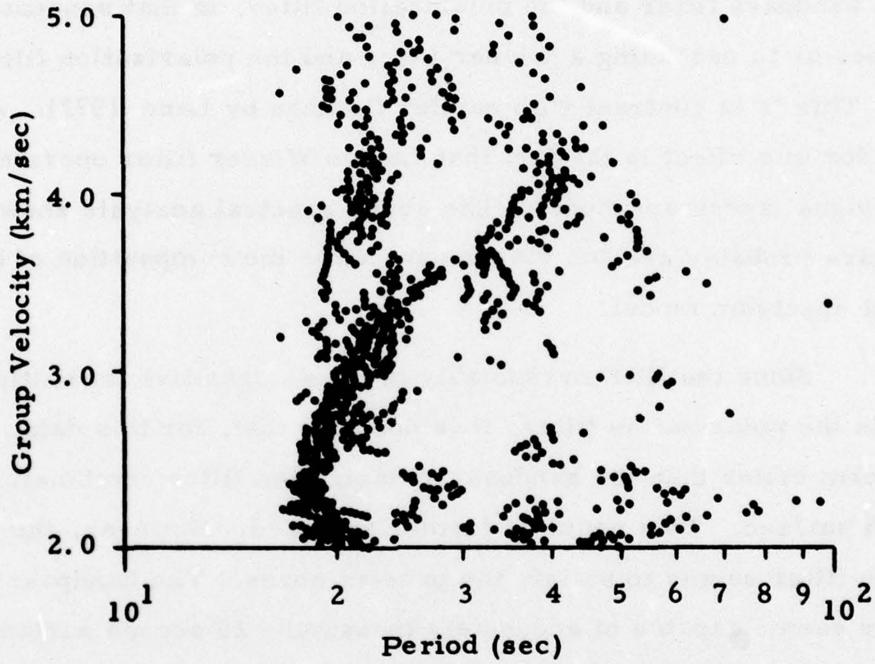


FIGURE II-2

KURILES/KAMCHATKA DISPERSION COMPOSITE
(5 Events)

The polarization filter results (Strauss, 1978), displayed for the five events analyzed in Figure II-3, show a rather weak response for the 3.0 to 4.5 km/sec velocity range. The response is much stronger between 2.0 and 3.0 km/sec. This is plausible, since multipathing would destroy the phase angle relationship on which the polarization filter operates. The polarization filter evaluation showed furthermore, that for this data base the cascading of a bandpass filter and the polarization filter, in that sequence, performed superior to cascading a Wiener filter and the polarization filter, respectively. This is in contrast with earlier findings by Lane (1977). A probable reason for this effect is the fact that Lane's Wiener filter operates with a composite signal spectrum model. The above spectral analysis shows that the signal spectra probably are too diverse to enable the composition of an efficient signal spectrum model.

Since the DRF presumably is not as sensitive to multipathing effects as is the polarization filter, it is possible that, for this data, the DRF would perform better than the bandpass-polarization filter combination between 3.0 and 4.5 km/sec. This could be further analyzed. However, the bandpass-polarization filter seems to satisfy the present needs. The bandpass-polarization filter seems capable of accurately measuring 20-second surface wave magnitudes at an event magnitude level which is approximately 0.5 M_s lower than the M_s measurement capability of bandpass filtering. This capability extends the M_s - m_b relationship for 20-second surface wave magnitudes into the lower magnitudes by 0.5 M_s in a reliable manner (Strauss, 1978).

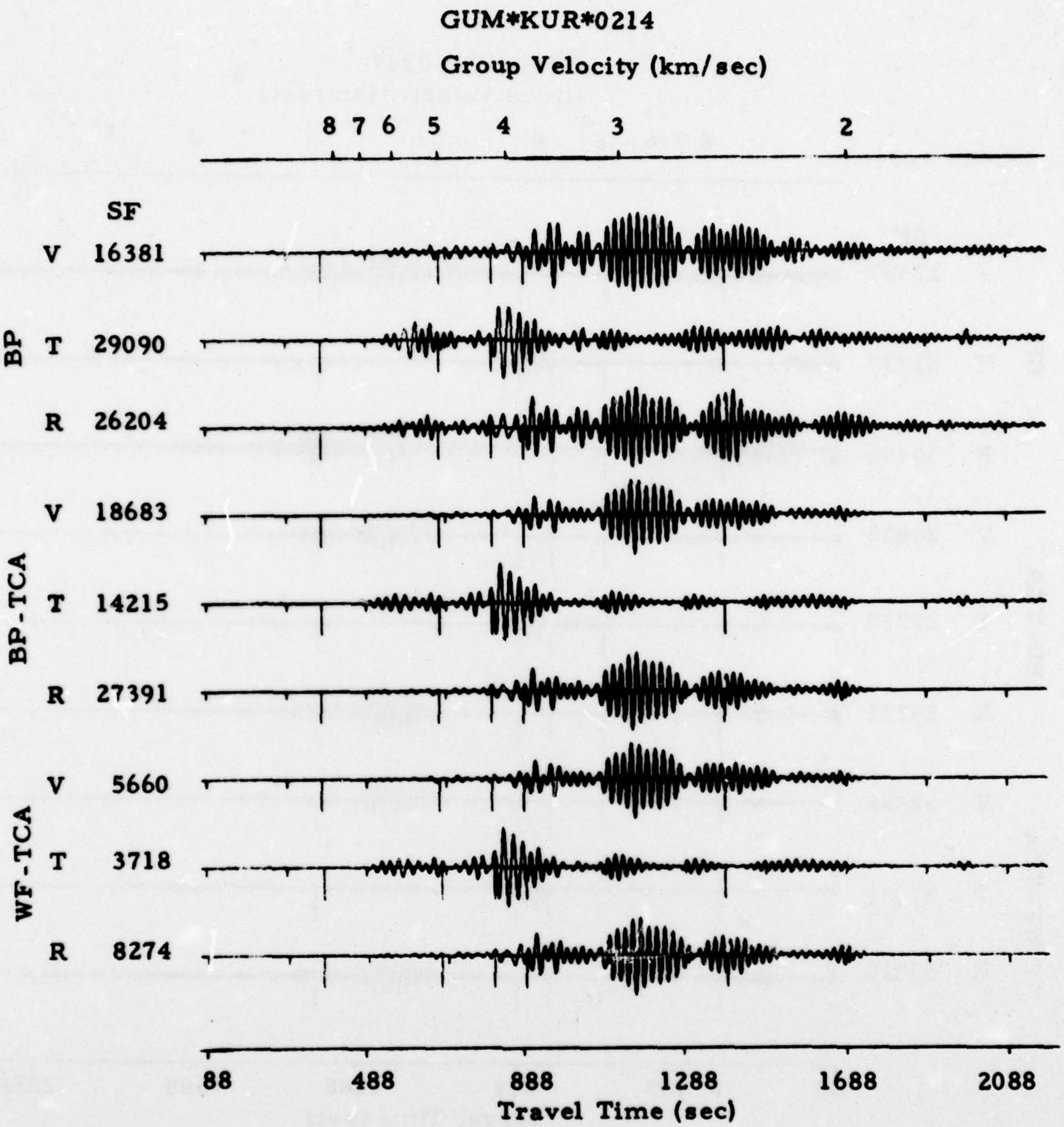


FIGURE II-3

POLARIZATION FILTER RESULTS (Strauss, 1978)
(PAGE 1 OF 5)

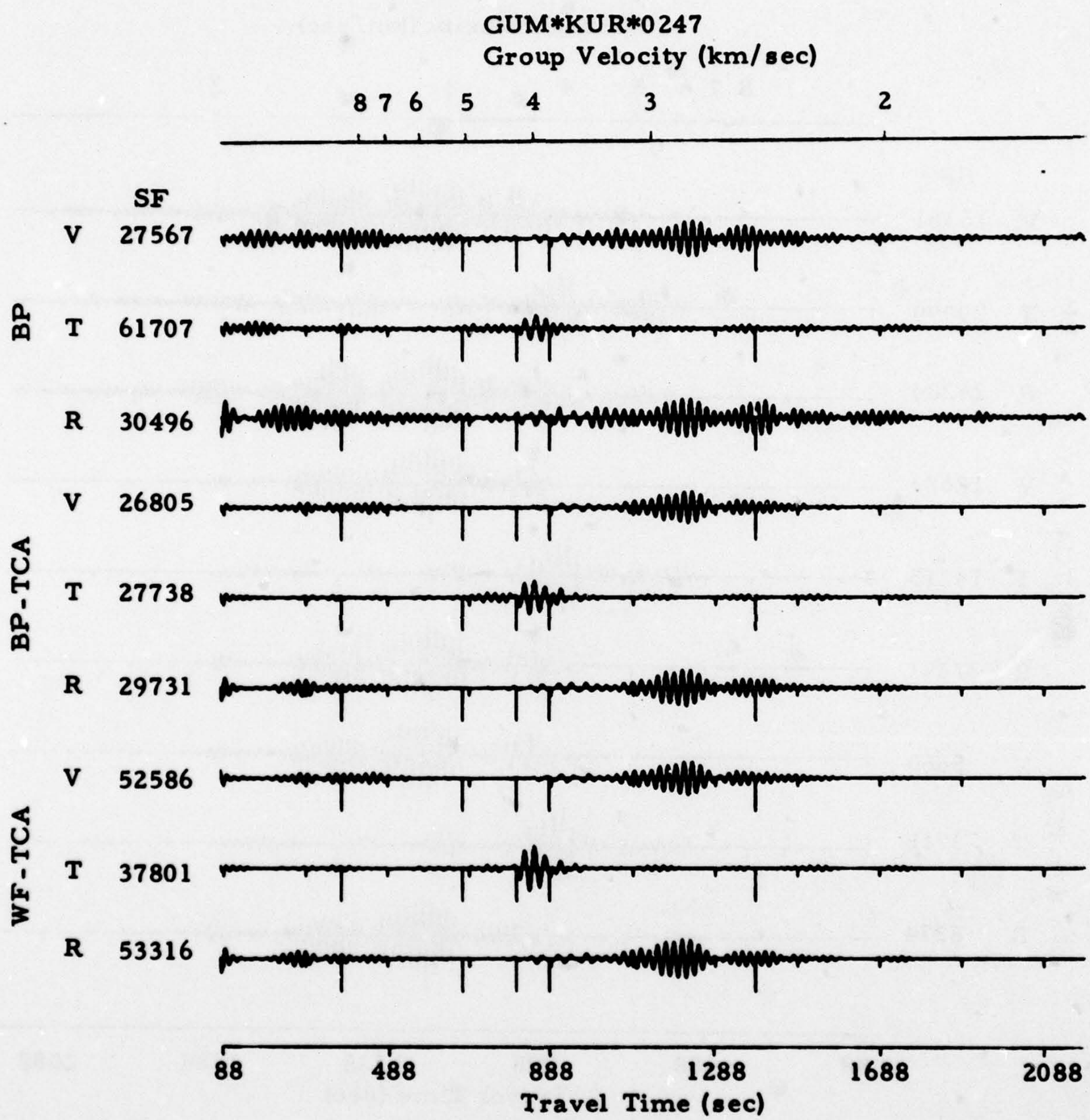


FIGURE II-3
POLARIZATION FILTER RESULTS (Strauss, 1978)
(PAGE 2 OF 5)

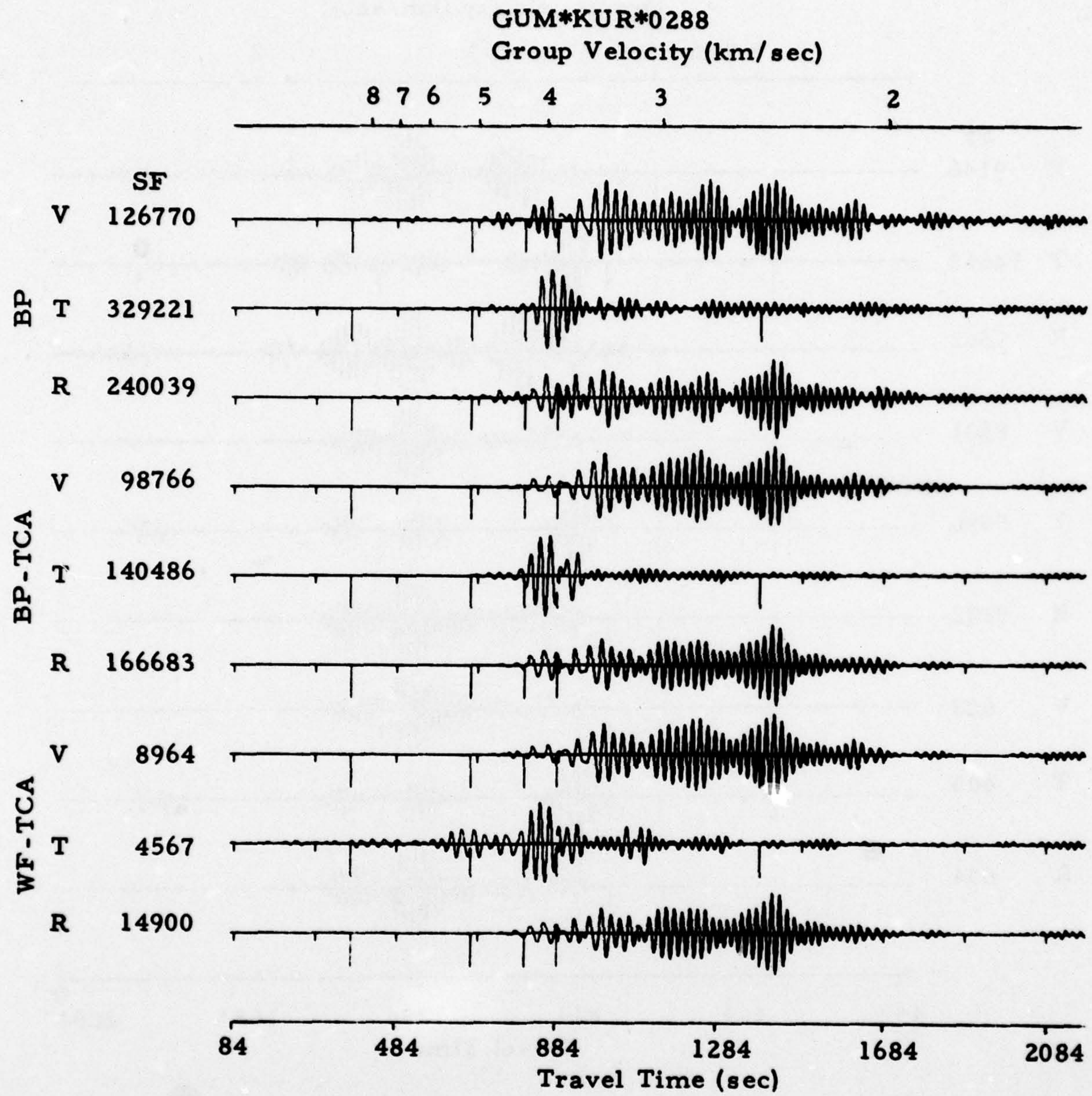


FIGURE II-3

POLARIZATION FILTER RESULTS (Strauss, 1978)
(PAGE 3 OF 5)

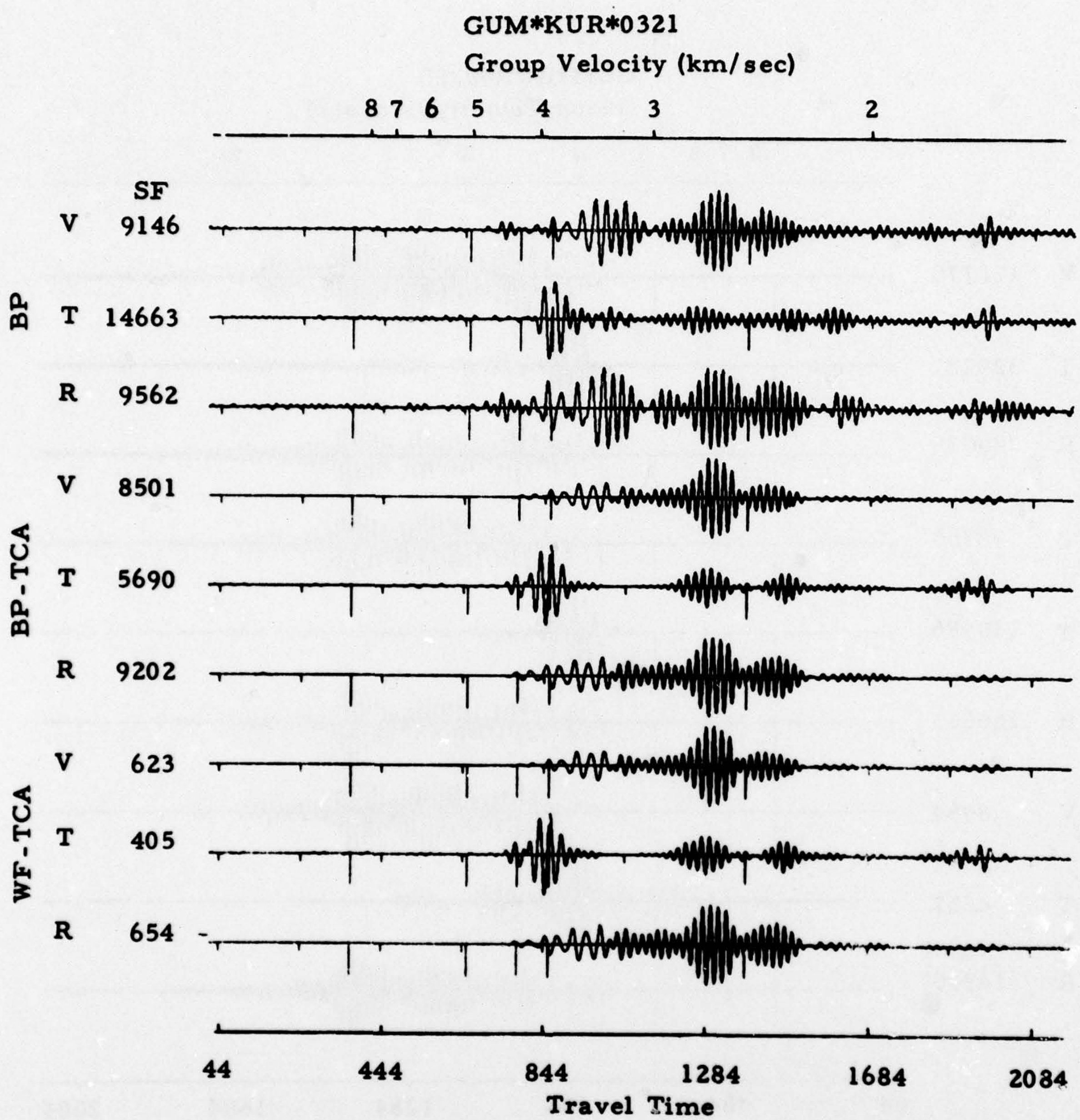


FIGURE II-3

POLARIZATION FILTER RESULTS (Strauss, 1978)
(PAGE 4 OF 5)

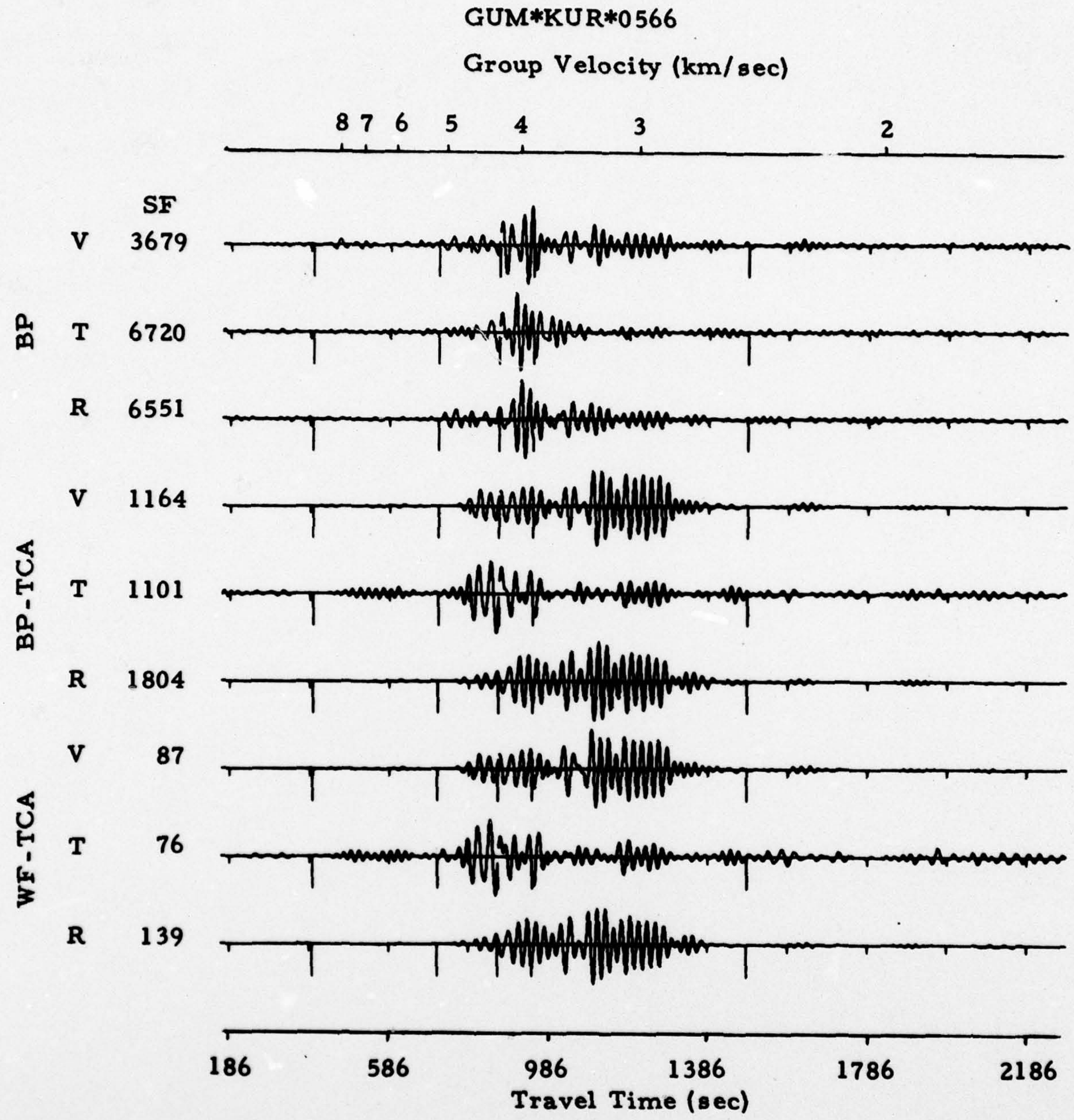


FIGURE II-3

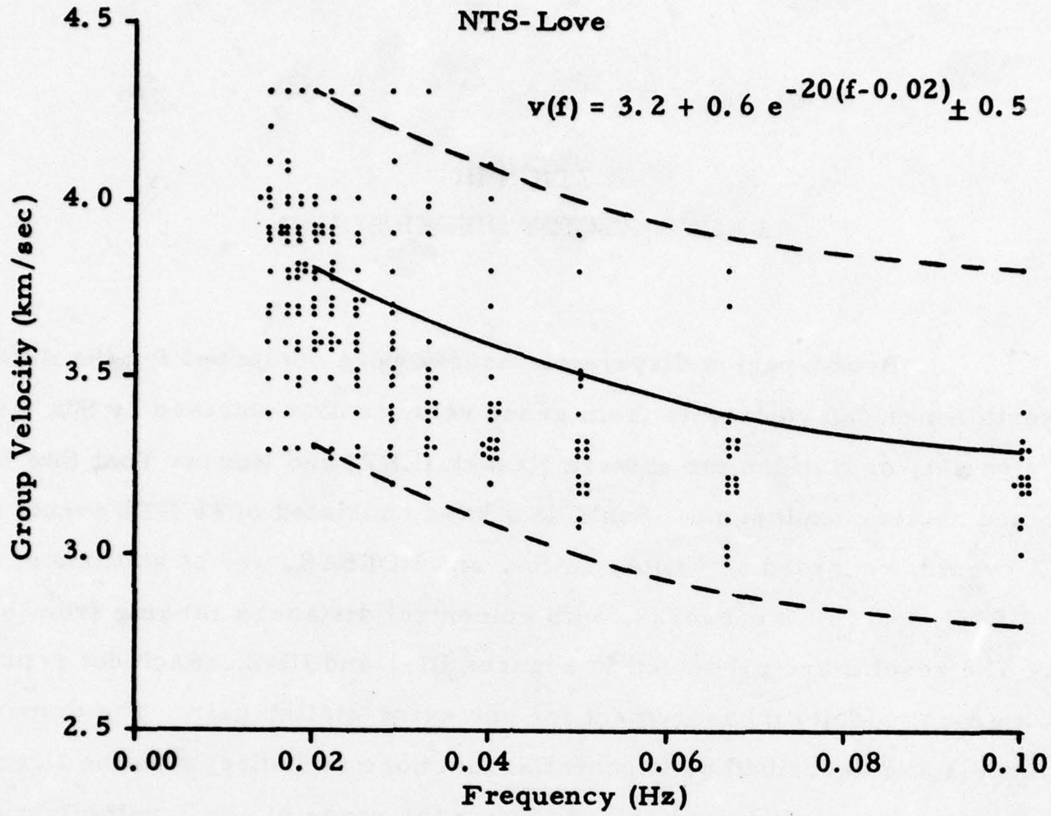
POLARIZATION FILTER RESULTS (Strauss, 1978)
(PAGE 5 OF 5)

SECTION III
BROAD-REGION DISPERSION

Broad-region dispersion models were composed for the Asian and North American continents from group velocity data obtained by Sun (1977) from a variety of stations for eastern Kazakh (EKZ) and Nevada Test Site (NTS) presumed nuclear explosions. Sun's data base consisted of 16 NTS events and 8 EKZ events, recorded at ALPA, LASA, and NORSAR, and at stations of the SRO, VLPE, and SDCS networks, with epicentral distances ranging from 8° to 138°. The results are presented in Figures III-1 and III-2. Each dot represents a group velocity measurement for one event-station pair. The dispersion models are described by exponential functions as indicated in the figures; these functions were fit empirically to cover the range of group velocity measurements between 0.02 and 0.10 Hz.

A special form of DRF for the special purpose of measuring frequency-dependent surface wave magnitudes can now be realized (Sax et al., 1978). A bank of narrowband filters, covering the frequencies of interest, is applied to the input waveform. For each center frequency an expected arrival time window is computed from the broad-region dispersion model. From each narrowband filter output the surface wave magnitude is then determined from the corresponding waveform window.

Of course, there is considerable spread (on the order of $\pm$ 0.5 km/sec) in the measured group velocities. Consequently, the resulting group velocity windows represent rather broad arrival time estimates. Nevertheless, these models should facilitate the measurement of frequency-dependent surface wave magnitudes for given broad regions.



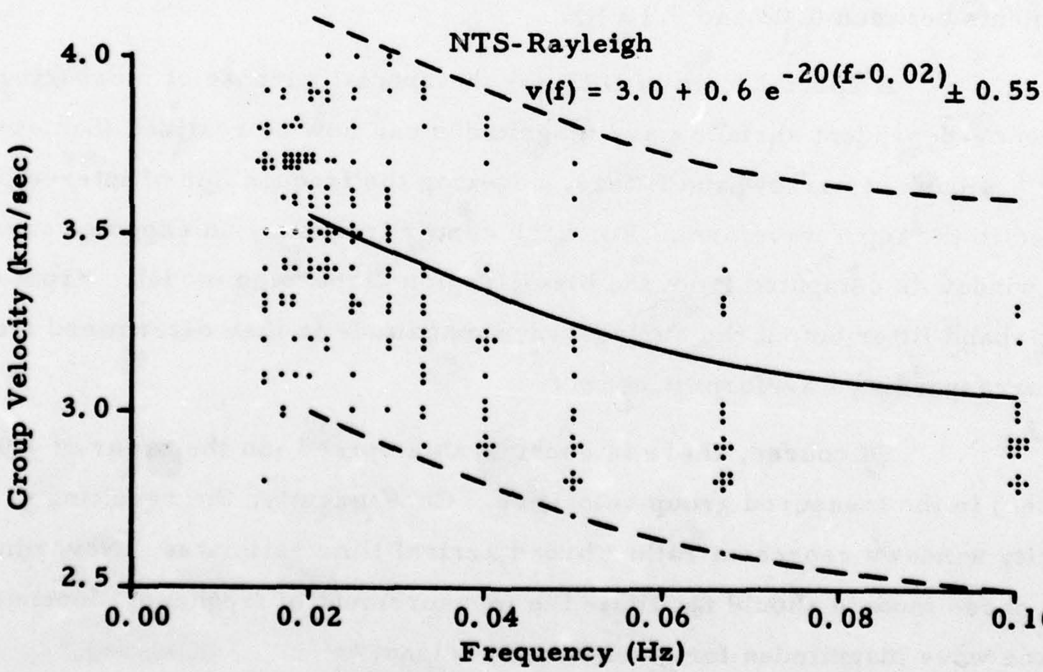
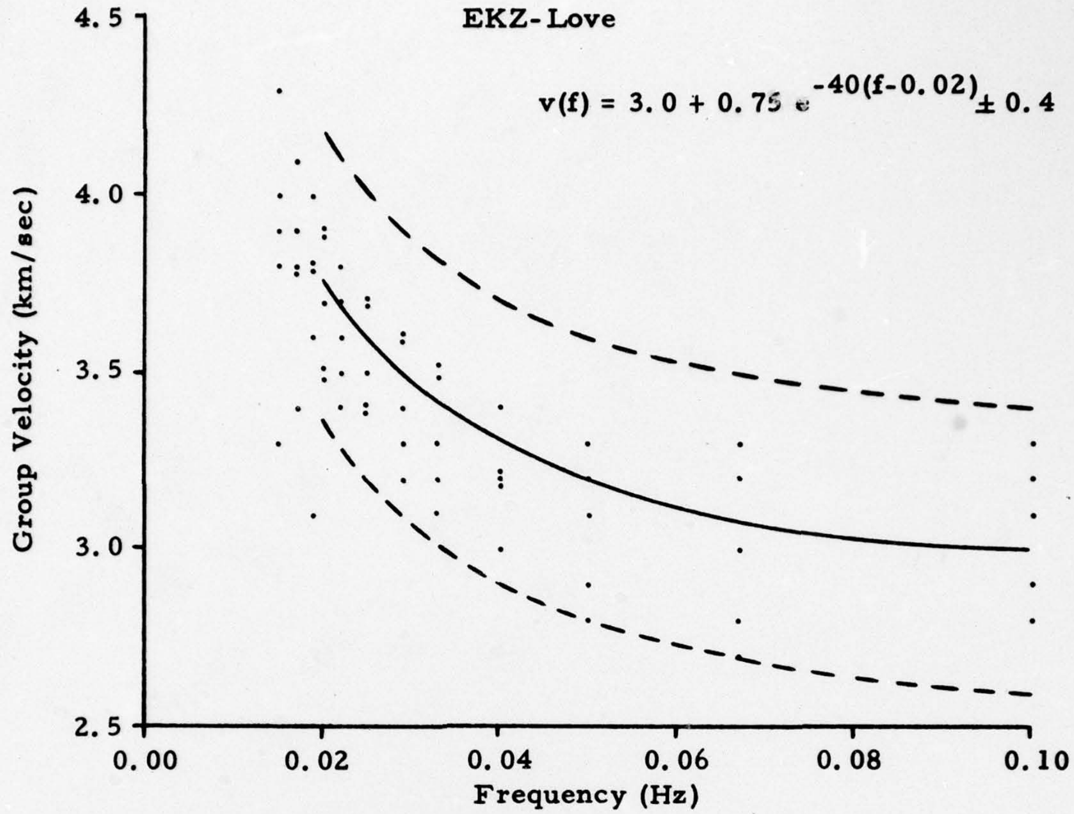


FIGURE III-1

NORTH AMERICAN CONTINENT DISPERSION FOR WORLD-WIDE STATIONS



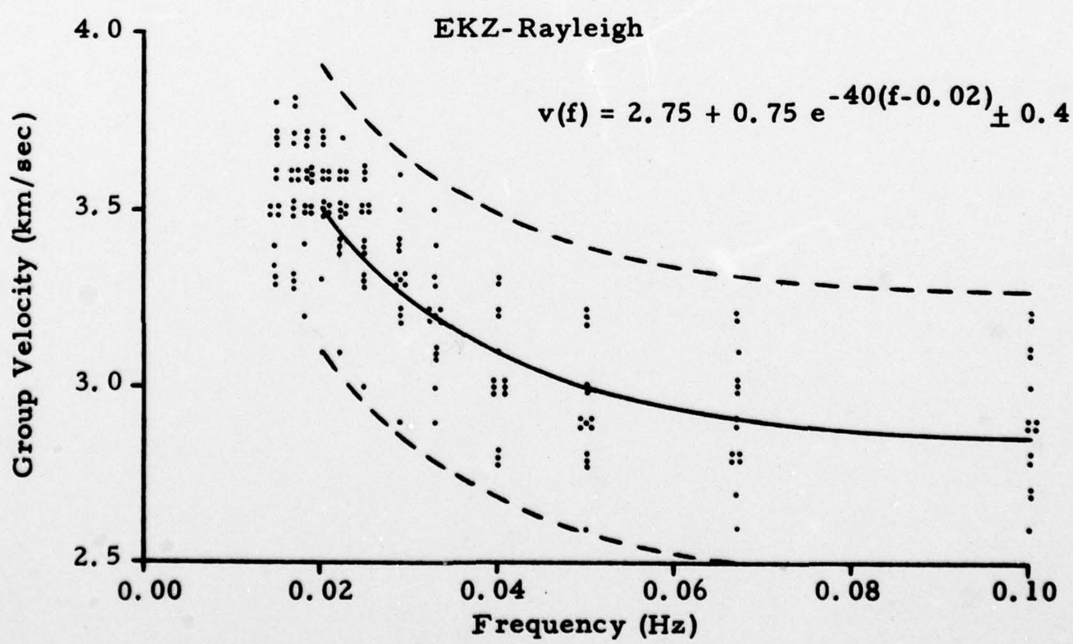


FIGURE III-2

ASIAN CONTINENT DISPERSION FOR WORLD-WIDE STATIONS

SECTION IV
SUMMARY

Examples of both narrow- and broad-region dispersion analysis have been presented. The narrow-region dispersion analysis for long-period surface wave propagation from Kuriles/Kamchatka to Guam shows considerable multipath structure in the 3.0 to 4.5 km/sec group velocity range. This multipathing jeopardizes polarization filter performance. In contrast, between 2.0 and 3.0 km/sec the 0.045 to 0.055 Hz frequency band signals are well defined, resulting in good polarization filter results (Strauss, 1978). These results seem to equal or surpass those projected for dispersion-related filtering (Unger, 1976). However, in the case of multipathing it is possible that a narrowband filtering process, such as dispersion-related filtering or variable-frequency magnitude measurement (Sax et al., 1978) perform better than polarization filtering; this needs further verification.

Broad-region dispersion models for the Asian and North American continents, generated from EKZ and NTS group velocity measurements, facilitate frequency-dependent surface wave magnitude measurements.

SECTION V

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